Small Scale Effects on the Brightness Temperature at 1.4 GHz: Ponding in an Agricultural Field

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Introduction

- Microwave radiometry is ideal for soil moisture retrieval
- L-band is the optimal frequency band
- Quantitative aspects of the soil moisture observations are not well known
- Validation of soil moisture measurements is a necessary step before remote sensing can effectively contribute to further scientific developments in hydrology, and prediction of global water and energy cycles

Methodology

Validation: The determination of the space-time statistical structure of the uncertainty of an algorithm or model output

- Validation of remotely-sensed observations of soil moisture through the quantization of the error between the radiative transfer models and radiometric soil moisture measurements
- Understanding the effect of diurnal changes of soil moisture profile, soil temperature profile, and roughness on brightness temperature
- Start with bare soil

Radiative Transfer Models

- Models generate the brightness temperature as a function of time

- Three models for the validation purposes:
  - Fresnel Model
  - Coherent Model (Njoku-Kong)
  - Incoherent Model

Model Descriptions

Fresnel Model:

- Single-layer model based on the Fresnel reflectivity equation
- Assumes that the dielectric and temperature profiles of the soil are uniform throughout the emitting layer
- It would be an appropriate model to implement in a satellite algorithm

Incoherent Model:

- The soil is treated as a layered dielectric medium
- Emissivity calculations are made on the basis of power rather than computing the field reflection coefficient
- Assumes that the medium consists of a number of scatterers that introduce a randomly distributed phase factor to the wave propagating between two points in the medium
- Propagation becomes an incoherent process described by the power density of the wave

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Coherent Model:

- Soil is treated as a layered dielectric medium
- Boundary conditions are applied to the layers to evaluate the electric fields in each layer and after several steps, the coherent emissivity of the system is calculated
- The model is based on the vertical profiles of temperature and soil moisture content

In this study, we are focusing on the coherent model

Test Case

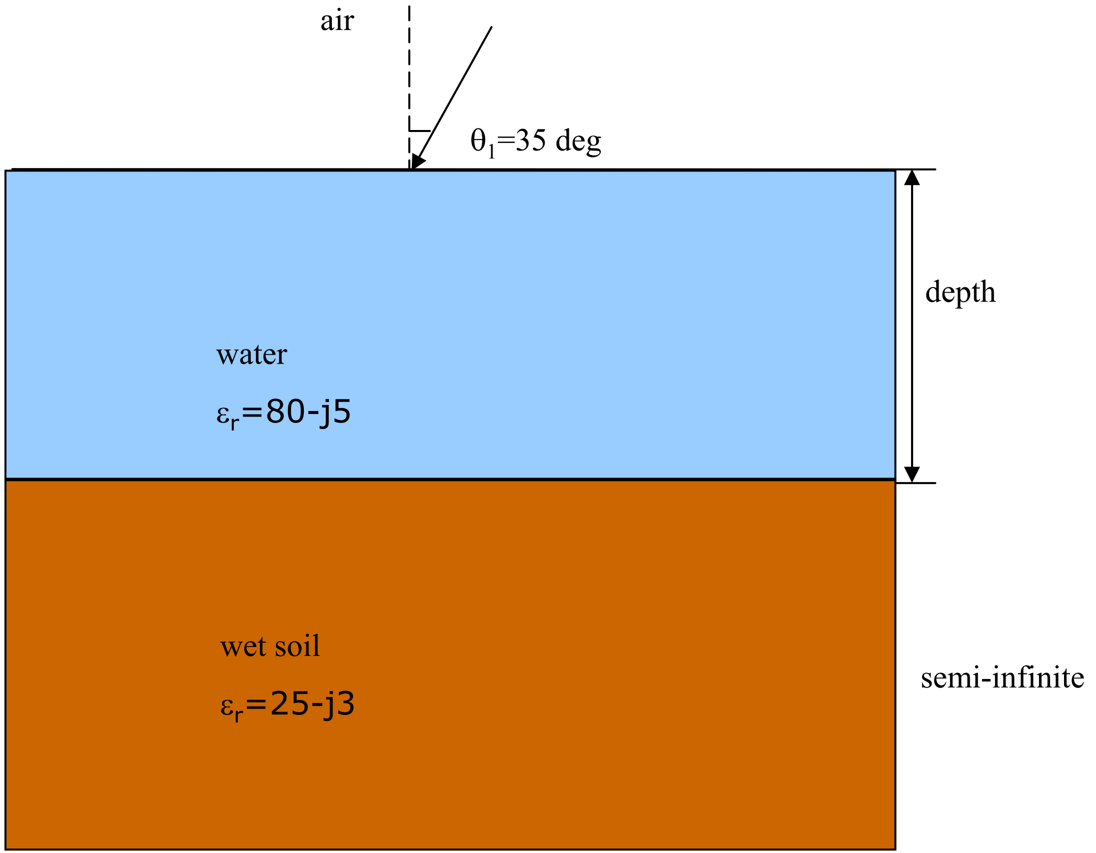


Figure 1. Test case geometry

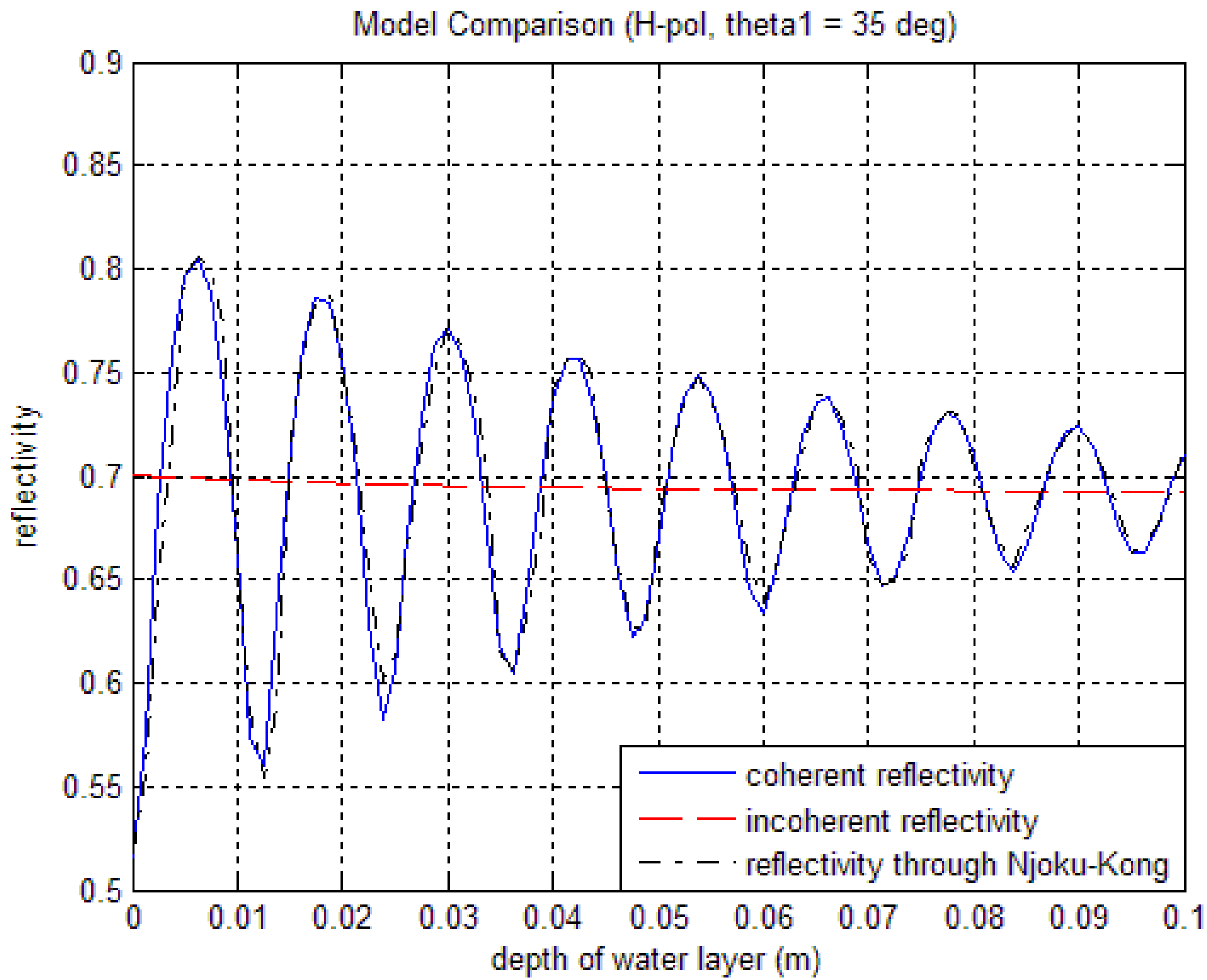


Figure 2. Reflectivity as a function of water layer thickness

ALEX

- ALEX: Atmosphere and Land-surface EXchange model
- The ALEX model is a land surface model that describes the transport of heat, water vapor and carbon within the soil-plant-atmosphere system
- Calculates the time-dependent soil moisture and soil temperature profiles
- Field measurements often provide an insufficient number of inputs to a radiative transfer models
- ALEX increases the accuracy of the radiative transfer models

Procedure

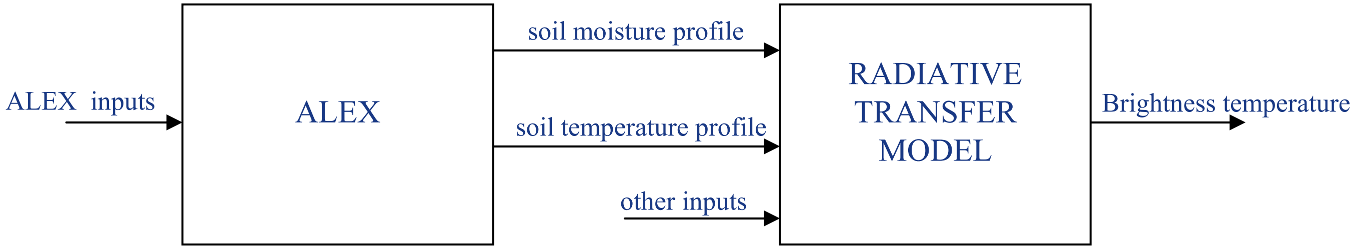


Figure 3. Steps to compute the brightness temperature

Measurements

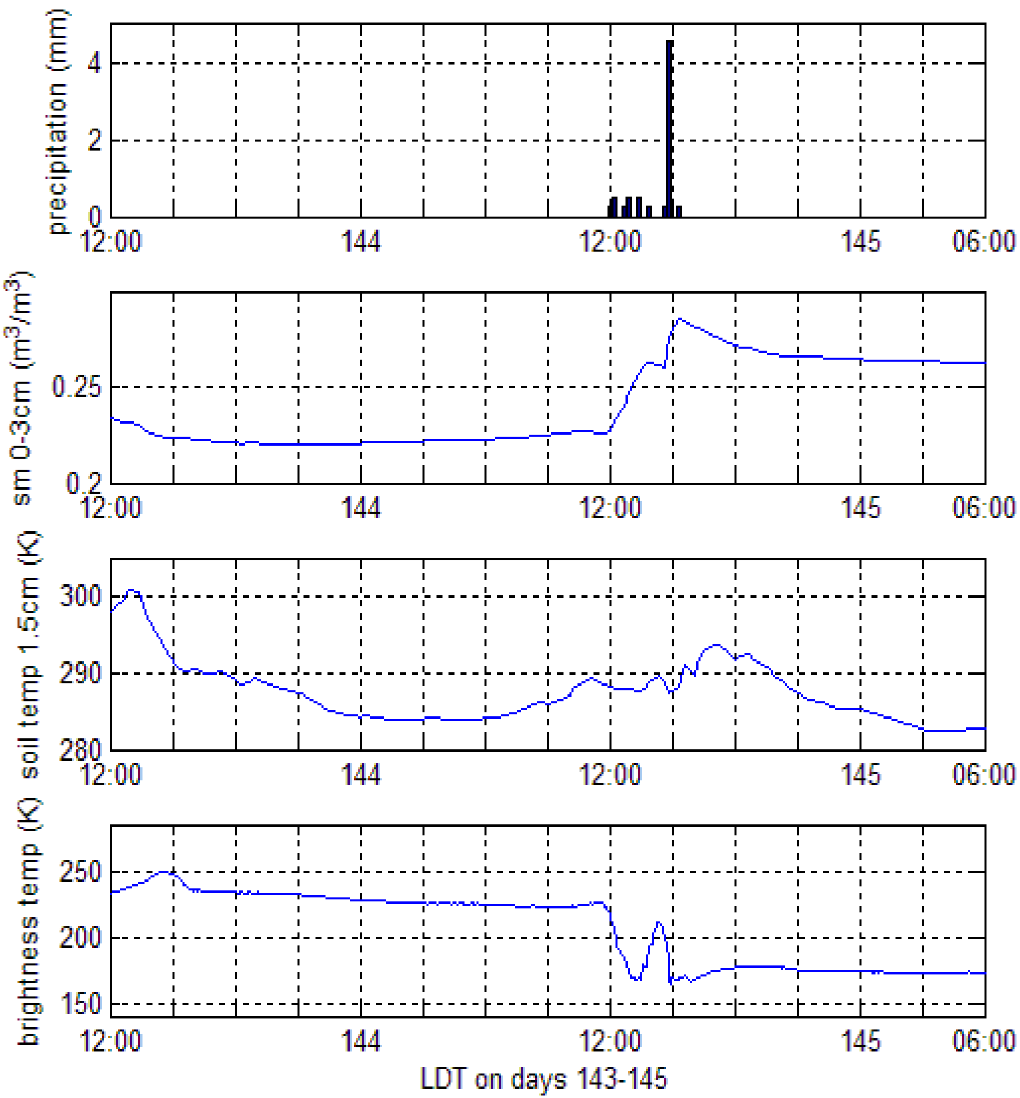


Figure 4. Measurement sets for the days 143.5-145.25

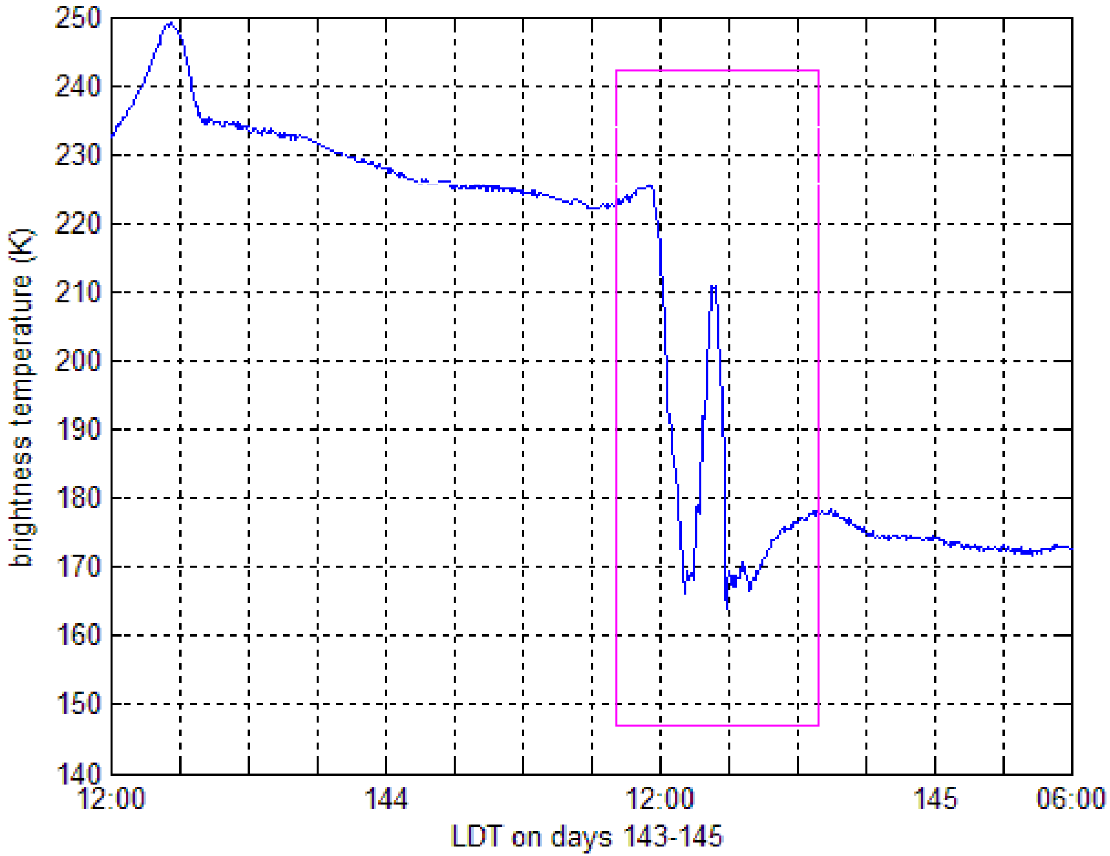
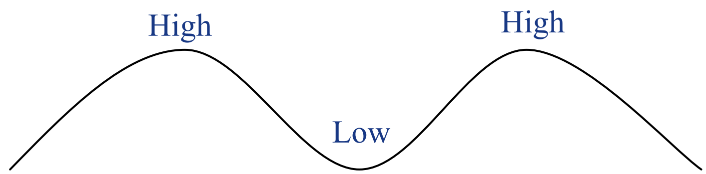


Figure 5. Measured brightness temperature

Hypothesis: Ponding is the main reason for the abrupt change in the brightness temperature

Figure 6. Picture taken in the field after precipitation

Approach

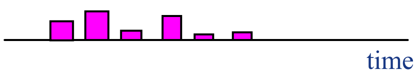


Step 1

Ponding allowed

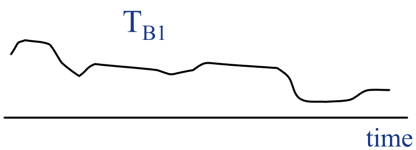
Reproduce ponding →

All *low*



Ponding included

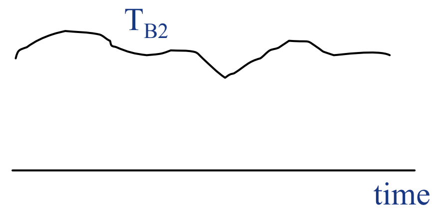
Reproduce T_{B1} →



Step 2

Ponding not allowed

Reproduce T_{B2} →

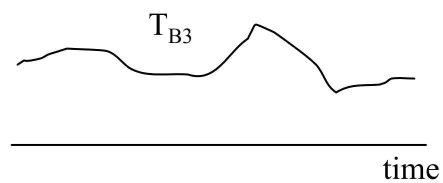


All *high*

Step 3

$$T_{B3} = \alpha T_{B1} + (1-\alpha)\, T_{B2}$$

Reproduce T_{B3} →



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Numerical Results

Ponding [cm]	T_B [K]
0.0	207.0679
0.5	165.7932
1.0	158.3149
1.5	170.8120
2.0	151.1655
2.5	183.9327
3.0	158.7879

Table 1. Ponding and the resulting brightness temperature values

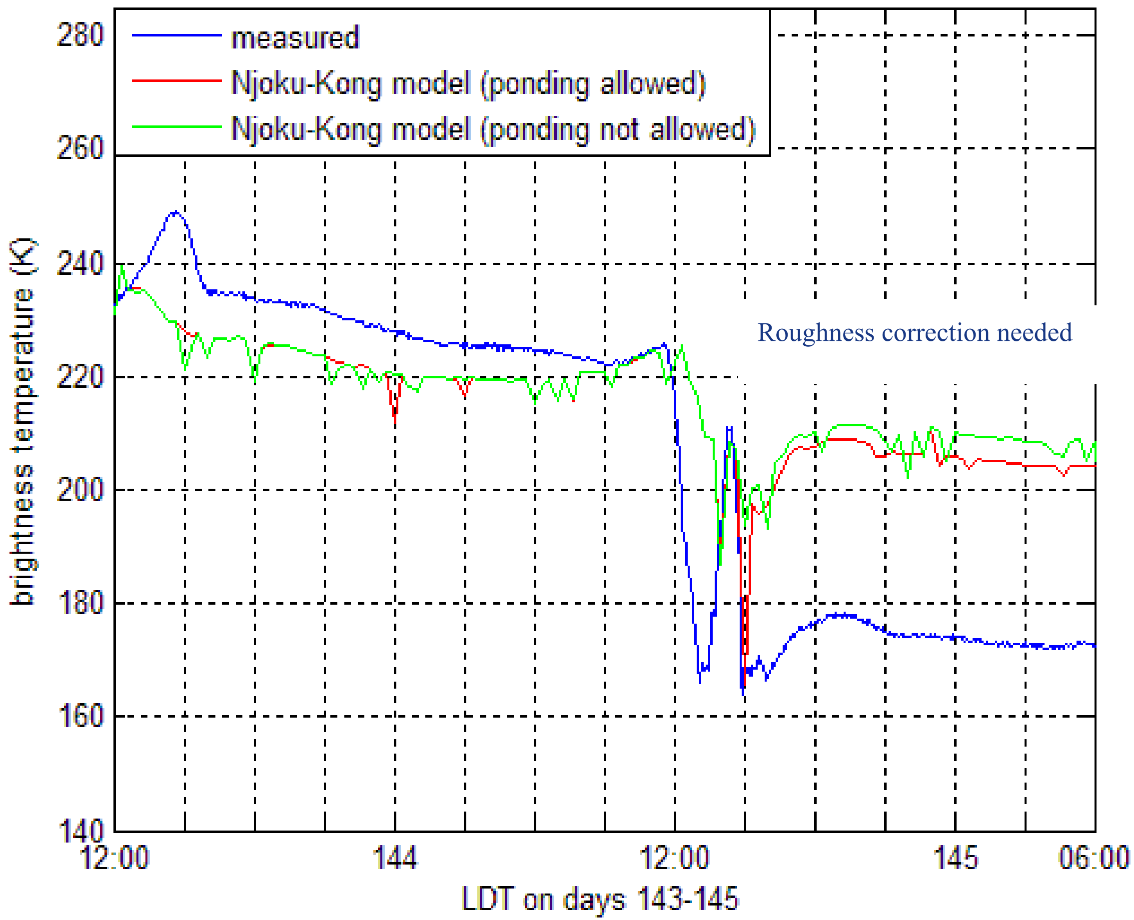

Figure 7. Measured and the modeled brightness temperatures (0.5 cm of ponding, no roughness correction)

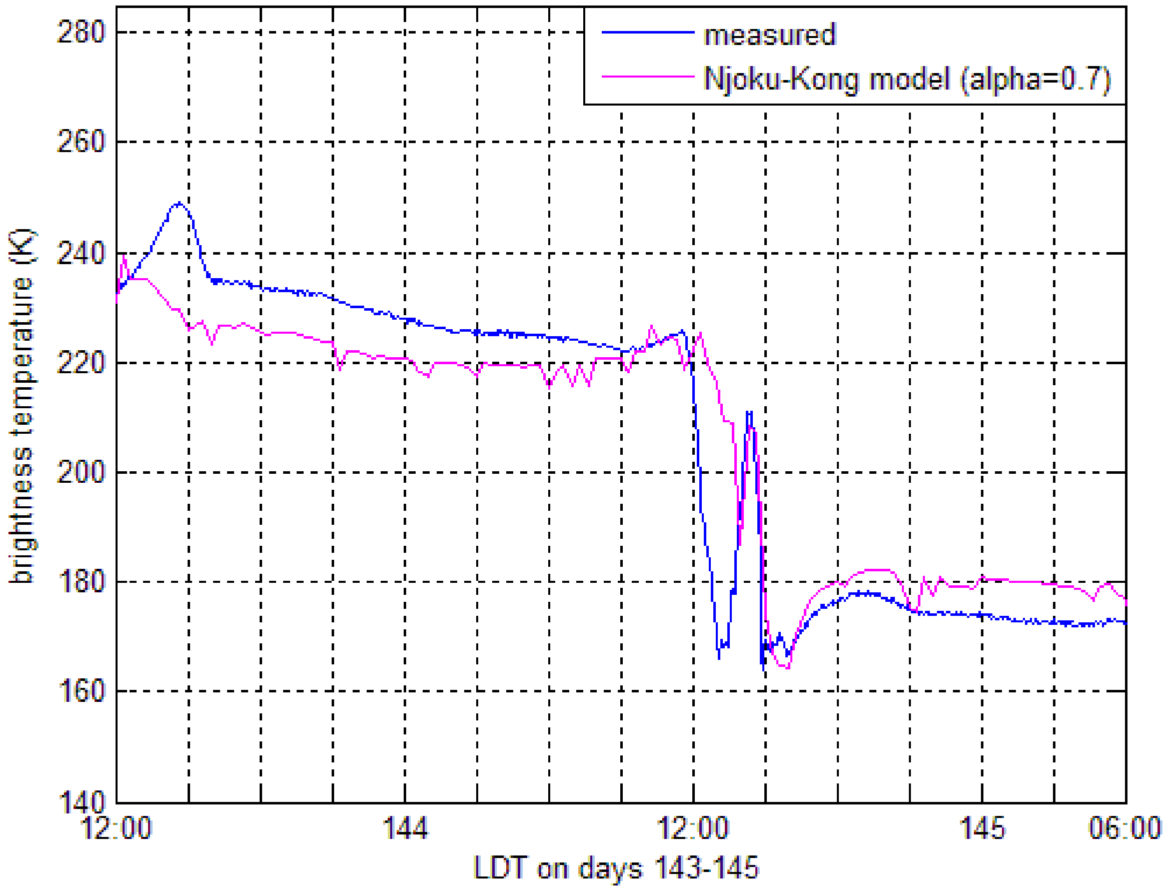

Figure 8. Measured and the modeled final brightness temperature (0.5 cm of ponding, α=0.7 with roughness correction)

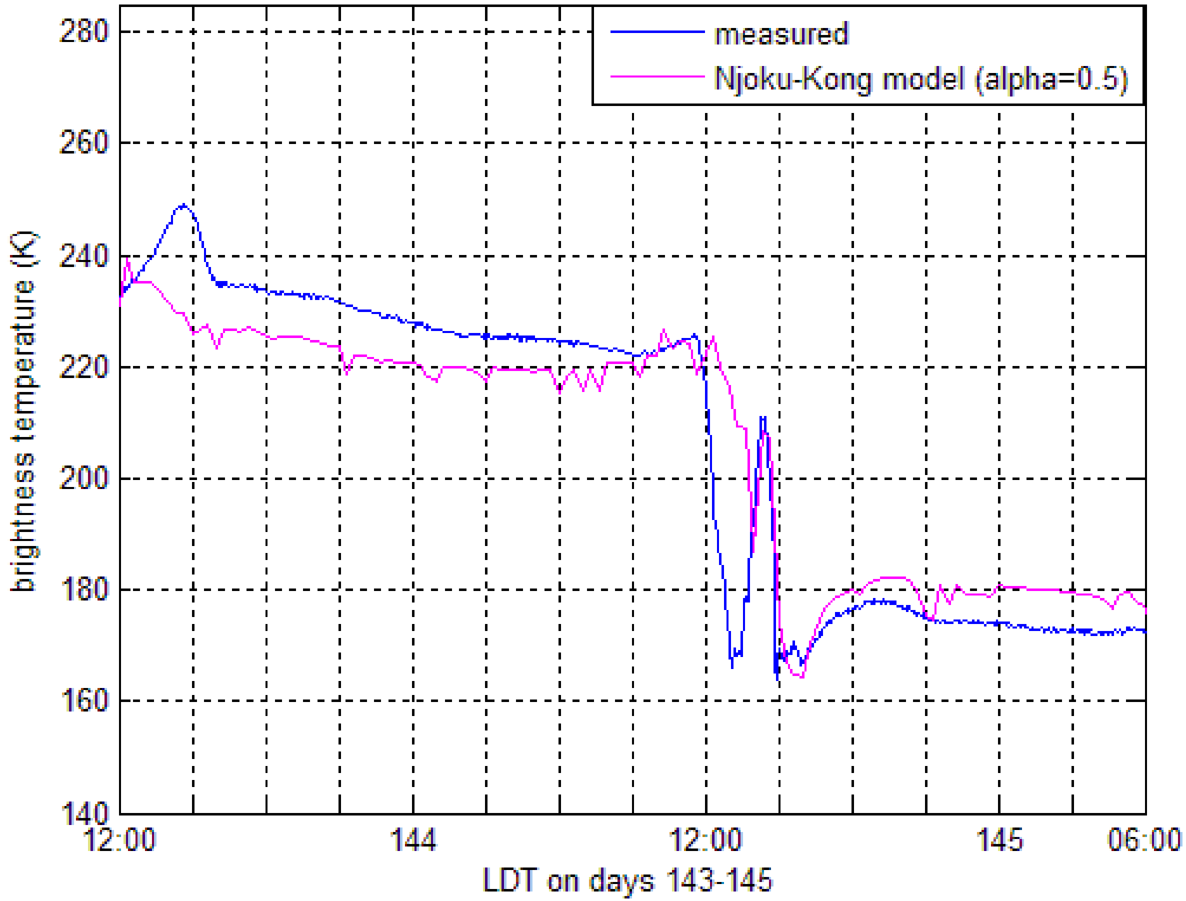

Figure 9. Measured and the modeled final brightness temperature (0.5 cm of ponding, α=0.5 with roughness correction)

Conclusion

- Validation is a necessary step before remote sensing can effectively contribute to further scientific developments
- An extreme change in the brightness temperature is investigated
- Ponding is shown to be the main reason
- Further investigation is needed to determine if ponding is frequent and significant
- Larger scales/satellite applications